Eur J Appl Physiol (2005) 94: 348–351
DOI 10.1007/s00421-004-1309-9

ORIGINAL ARTICLE

Duane Knudson · Guillermo Noffal

Time course of stretch-induced isometric strength deficits

Received: 19 May 2004 / Accepted: 8 December 2004 / Published online: 16 February 2005

Abstract Stretching in the warm-up was been shown to decrease several muscular performance variables, but the dose-response of this effect is unknown. This study documented the change in isometric grip strength over ten trials in a convenience sample of young adults randomly assigned to control ($n=22$) or repeated bouts of 10-s static stretches of the wrist flexors ($n=35$). There was a significant ($P<0.05$) difference in the change in mean normalized grip strength between the control and stretching groups that was not significantly different across gender. Grip strengths in the control group were consistent with a linear trend, while the grip strengths in the stretching group declined in a logarithmic fashion to 88.8% with 100 s of stretching. Statistically significant ($P<0.05$) differences in normalized grip strength between the two groups appeared after 40 s of stretching. Meaningful decreases in isometric grip strength following static stretching are likely to appear in young adults following 20–40 s of static stretching.

Keywords Static stretching · Grip · Wrist flexors · Flexibility

Introduction

Several studies have reported significant decreases in muscular strength following stretching (Avela et al. 1999; Evetovich et al. 2003; Fowles et al. 2000; Nelson and Kokkonen 2001; Nelson et al. 2001; Rosenbaum and Hennig 1995; Kokkonen et al. 1998). This strength deficit is a result of decreased contractile forces and neuromuscular drive (Avela et al. 1999; Fowles et al. 2000) and persists for about 60 min (Fowles et al. 2000). These decreases in muscular performance were also observed in complex movements like jumping (Cornwell et al. 2001; McNeal and Sands 2003; Young and Behm 2003).

Some studies of this phenomenon and the viscoelastic response of human muscles have used unusually long (90 s to over 30 min) and possibly unrealistic stretching protocols for individual muscle groups in actual practice (Avela et al. 1999; Fowles et al. 2000; Kokkonen et al. 1998; Magnusson et al. 1996; Rosenbaum and Hennig 1995). It is not clear what dose of stretching induces significant decreases in muscular performance, and it is possible that a dose-dependent effect of stretching could explain why some studies have reported non-significant trends of decreased muscular performance following stretching (Knudson et al. 2001, 2004; Koch et al. 2003; Thigpen 1989; Young et al. 2004). The purpose of this study was to document the time course of decreases in isometric grip strength following repeated 10-s static stretches of the wrist flexors. It was hypothesized that stretching would result in a greater decrease in grip strength than not stretching.

Methods

A convenience sample of 57 young adults (33 males and 24 females) from two universities gave informed consent to participate in the study. Twenty-two of the subjects were randomly assigned to control group with the remaining 35 subjects assigned to a stretching group. Subject demographics and initial grip strengths were similar between the two groups.

The subjects reported basic demographic information and were instructed on the experimental protocol. The protocol consisted of a warm-up routine followed by 14 three-second maximal isometric grip strength tests with a hydraulic hand dynamometer (Jaymar 5030J1).

D. Knudson (✉)
Department of Kinesiology, California State University,
First and Normal Street, Chico, CA 95929-0330, USA
E-mail: dknudson@csuchico.edu
Tel.: +1-530-8986060
Fax: +1-530-8984932

G. Noffal
California State University, Fullerton, CA, USA

Dynamometer calibration was checked before and after the study. Subjects performed grip strength tests in a standing position with their dominant arm extended, in neutral forearm pronation/supination and wrist flexion/extension. The grip width of the dynamometer was placed in the middle position that corresponded to width (5–6 cm), where maximum strength occurs for both men and women (Petrofsky et al. 1980). Isometric grip strength is a reliable variable with considerable normative data (Mathiowetz et al. 1985) and clinical utility (Richards and Palmiter-Thomas 1996).

The warm-up consisted of 1 min of gradual swinging a tennis racket with wrist flexion and extension in the transverse plane. Subjects performed four maximum grip strength tests with 1-min rest between tests to complete the warm-up and learn the strength testing protocol. Previous research has shown that three to four trials are needed to eliminate warm-up and learning effects in maximal grip strength testing (Dunwoody et al. 1996). The largest grip strength of the four tests was recorded as the initial grip strength.

After a 1-min rest, the subjects then performed 10 three-second maximal grip strength tests separated by 1-min intervals. This 1-min inter-test rest was shown to provide stable repeat grip strength recordings (Reddon et al. 1985; Trossman and Li 1989). During the 1-min rest interval, the control subjects did nothing while the stretch subjects performed a 10-s static stretch of the wrist flexors half way through the rest interval. Stretching subjects were instructed to passively pull the fingers of the dominant hand with their opposite hand and "hold just before the point of discomfort" to perform stretches of the wrist flexor muscles. Subjects performed the stretch in a standing position, with their shoulder flexed (to horizontal), forearm supinated, elbow extended and wrist hyper-extended.

To facilitate comparisons and to decrease variability due to differences in size, grip strengths were expressed as a percentage of the initial grip strength. Mean normalized grip strengths for the control and stretching groups were examined with a 2 by 2 (group by gender) repeated-measures MANOVA using JMP (SAS Institute) software. Statistical significance was accepted at the $P<0.05$ level and a significant effect of stretching across trials was followed up by t tests between the control and stretching group. The pattern of mean normalized grip strengths over time were modeled by best-fitting polynomials.

Results

Mauchly's test of sphericity was significant ($P<0.05$), so the Greenhouse-Geisser adjustments were used. There was a significant ($F=13.3$, $P<0.0001$) effect of trials on mean normalized grip strength. There was no significant ($F=0.69$, $P<0.65$) interaction of gender and time or three-way interaction (trials•gender•group), so subsequent analyses collapsed data across gender. The significant ($F=2.89$, $P<0.01$) interaction of trials and group indicated that the change in grip strength across trials in the stretching group was different from the control group. This difference was mirrored by a linear best fit ($r^2=0.60$, SEE = 1.2%) to the control group data, but a logarithmic fit ($r^2=0.92$, SEE = 0.7%) to the stretching group data (Fig. 1). The mean normalized grip strengths and t test comparisons between trials of each group are reported in Table 1. Statistically significant ($P<0.05$) differences in mean normalized grip strength between the control and stretching group began after 40 s of static stretching (Table 1).

Discussion

The variability of mean normalized grip strength across trials in the control subjects was quite small (SD = 1.8%), demonstrating that the experimental protocol minimized confounding effects of learning or fatigue. This variability was within normal variation (CV 4–5%) of maximal grip strength tests (Dvir 1999; Hamilton-Fairfax et al. 1995). Mean grip strength in the control group was best fit by a linear equation (SEE = 1.2%) that predicted a gradual decline in

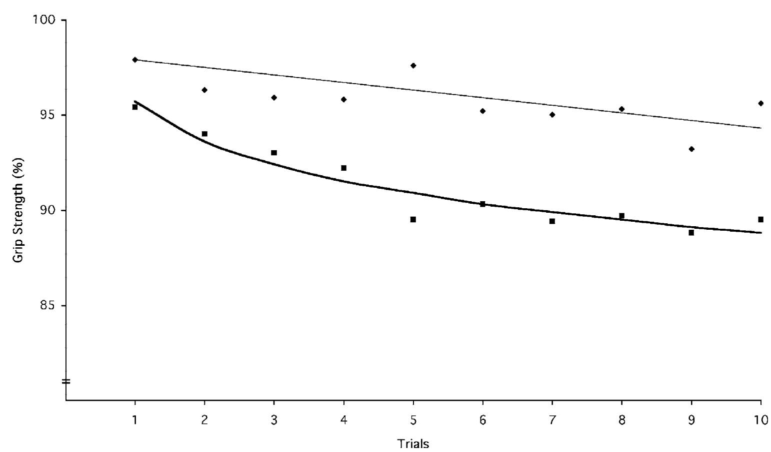

Fig. 1 Mean normalized grip strength across trials. Control group data (*filled diamond*) were best fit by a line [NGS = 98.3 − 0.42•trial] and stretch group data were best fit by a logarithmic function [NGS = 95.7 − 3.0log(trial)]

Table 1 Mean and SD normalized grip strengths in the control and stretching group

Trial	Control	Stretch
1	97.9 (4.9)	95.4 (5.2)
2	96.3 (7.5)	94.0 (7.3)
3	95.9 (5.5)	93.0 (5.8)
4	95.8 (5.8)	92.2 (6.6)*
5	97.6 (6.9)	89.5 (7.6)**
6	95.2 (4.7)	90.3 (8.0)*
7	95.0 (6.9)	89.4 (6.7)**
8	95.3 (6.6)	89.7 (7.6)**
9	93.2 (8.4)	88.8 (8.4)*
10	95.6 (9.3)	89.5 (8.3)*

Stretch significantly different from control: $^{*}P < 0.05$; $^{**}P < 0.01$

strength to a clinically meaningful level (5%) over nine trials (Fig. 1). This was nominally better than concluding there was no change in grip strength, where fitting the mean had a SD of 1.8%. Previous research has shown nearly flat linear trends in repeated grip strength tests separated by 1 min (Reddon et al. 1985).

The MANOVA and curve fits supported the hypothesis of a greater decrease in isometric grip strength following stretching. This effect did not differ across gender. Grip strength following stretching showed an exponential decline that was best fit by a logarithmic function. Strength decreases with additional stretching continued up to 11.2 percent after 100 s of stretching. The leveling off of strength decrements parallels the exponential changes in range of motion and stress relaxation following repeated bouts of stretching (Magnusson 1998; Taylor et al. 1990). While the logarithmic function shows an immediate decrease in isometric grip strength following stretching, there are several factors that must be considered in establishing the dose-response of stretching to decreases in strength.

Factors affecting dose-response between stretching and muscular strength are between-subject variability, statistical significance, and clinical significance. There was some variability in the response of subjects to repeated testing and the response to stretching (see SD in Table 1) that likely contributed to the statistically significant ($P < 0.05$) differences between the control and stretching group appearing after 40 s of stretching. Physiologically meaningful decreases in grip strength in normal subjects could considered to be five percent, which could support a conclusion of a 20 s dose (log fit in Fig. 1) of static stretching to create meaningful mean decrease in grip strength. It is likely that a static stretching dose between 20 s and 40 s is required to decrease isometric grip strength in most young adults like the ones studied.

This study was limited to the responses of a convenience sample of young adults, who would be representative of moderately to vigorously active young persons. It is not clear how these results on the isometric strength of the forearm and hand might related to other high-force muscular performance in other muscles groups or subject populations. More research is needed on the dose-response of stretching on muscular performance in a variety of muscles, movements, and subject populations.

In summary, static stretching of the forearm and hand resulted in significant decreases in isometric grip strength in young adults. The shape of this decrease is a logarithmic function, with clinically meaningful decreases in strength beginning to emerge between 20 s and 40 s of static stretching.

References

Avela J, Kyrolainen H, Komi PV (1999) Altered reflex sensitivity after repeated and prolonged passive muscle stretching. J Appl Physiol 86:1283–1291

Cornwell A, Nelson AG, Heise GD, Sidaway B (2001) Acute effects of passive muscle stretching on vertical jump performance. J Hum Mov Stud 40:307–324

Dunwoody L, Tittmar HG, McClean WS (1996) Grip strength and intertrial rest. Percept Mot Skills 83:275–278

Dvir Z (1999) Coefficient of variation in maximal and feigned static and dynamic grip efforts. Am J Phys Med Rehabil 78:216–221

Evetovich TK, Nauman NJ, Conley DS, Todd JB (2003) Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. J Strength Cond Res 17:484–488

Fowles JR, Sale DG, MacDougall JD (2000) Reduced strength after passive stretch of the human plantar flexors. J Appl Physiol 89:1179–1188

Hamilton-Fairfax A, Balnave R, Adams RD (1995) Variability of grip strength during isometric contraction. Ergonomics 38:1819–1830

Knudson D, Bennett K, Corn R, Leick D, Smith C (2001) Acute effects of stretching are not evident in the kinematics of the vertical jump. J Strength Cond Res 15:98–101

Knudson D, Noffal G, Bahamonde R, Bauer J, Blackwell J (2004) Stretching has no effect on tennis serve performance. J Strength Cond Res 18:654–656

Koch AJ, O'Bryant HS, Stone ME, Sanborn K, Proulx C, Hruby J, Shannonhouse E, Boros R, Stone M (2003) Effect of warm-up on the standing broad jump in trained and untrained men and women. J Strength Cond Res 17:710–714

Kokkonen J, Nelson AG, Cornwell A (1998) Acute muscle stretching inhibits maximal strength performance. Res Q Exerc Sport 69:411–415

Magnusson SP (1998) Passive properties of human skeletal muscle during stretch maneuvers: a review. Scand J Med Sci Sports 8:65–77

Magnusson SP, Simonsen EB, Aagaard P, Kjaer M (1996) Biomechanical responses to repeated stretches in human hamstring muscle in vivo. Am J Sports Med 24:622–628

Mathiowetz V, Kashman N, Vollard G, Weber K, Dowe M, Rogers S (1985) Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil 66:69–74

McNeal JR, Sands WA (2003) Acute static stretching reduces lower extremity power in trained children. Pediatr Exerc Sci 15:139–145

Nelson AG, Kokkonen J (2001) Acute ballistic muscle stretching inhibits maximal strength performance. Res Q Exerc Sport 72:415–419

Nelson AG, Allen JD, Cornwell A, Kokkonen J (2001) Inhibition of maximal voluntary isometric torque production by acute stretching is joint-angle specific. Res Q Exerc Sport 72:68–70

Petrofsky JS, Williams C, Kamen G, Lind AR (1980) The effect of handgrip span on isometric exercise performance. Ergonomics 23:1129–1135

Reddon JR, Stefanyk WO, Gill DM, Renney C (1985) Hand dynamometer: effects of trials and sessions. Percept Mot Skills 61:1195–1198

Richards L, Palmiter-Thomas P (1996) Grip strength measurement: a critical review of tools, methods, and clinical utility. Crit Rev Phys Rehabil Med 8:87–109

Rosenbaum D, Hennig E (1995) The influence of stretching and warm-up exercises on achilles tendon reflex activity. J Sport Sci 13:481–490

Taylor DC, Dalton JD, Seaber AV, Garrett WE (1990) Viscoelastic properties of muscle-tendon units. Am J Sports Med 18:300–309

Thigpen LK (1989) Effect of statically performed toe touch stretches on torque production of the hamstring and quadriceps muscles groups. J Hum Mov Stud 17:71–88

Trossman PB, Li PW (1989) The effect of duration of intertribal rest periods on isometric grip strength performance in young adults. Occup Ther J Res 9:362–378

Young WB, Behm DG (2003) Effects of running, static stretching and practice jumps on explosive force production and jumping performance. J Sports Med Phys Fit 43:21–27

Young W, Clothier P, Otago L, Bruce L, Liddell D (2004) Acute effects of static stretching on hip flexor and quadriceps flexibility, range of motion and foot speed in kicking a football. J 1Sci Med Sport 7:23–31